



Commercial Crew Program and the Safety Technical Review Board

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Commercial Crew Program Safety Technical Review Board

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The Commercial Crew Program (CCP) is unique to any other program office at NASA. After the agency suffered devastating budget cuts and the Shuttle Program retired, the U.S. gave up its human spaceflight capabilities. Since 2011 the U.S. has been dependent on Russia to transport American astronauts and cargo to the International Space Station (ISS) and back. NASA adapted and formed CCP, which gives private, domestic, aerospace companies unprecedented reign over America's next ride to space. The program began back in 2010 with 5 companies and is now in the final phase of certification with 2 commercial partners. The Commercial Crew Program is made up of 7 divisions, each working rigorously with the commercial providers to complete the certification phase. One of these 7 divisions is Systems Engineering and Integration (SE&I) which is partly comprised of the Safety Technical Review Board (STRB). The STRB is primarily concerned with mitigating improbable, but catastrophic hazards. It does this by identifying, managing, and tracking these hazards in reports. With the STRB being in SE&I, it significantly contributes to the overall certification of the partners' vehicles. After the partners receive agency certification approval, they will have the capability to provide the U.S. with a reliable, safe, and cost-effective means of human spaceflight and cargo transport to the ISS and back.

Nomenclature

<i>CCDev1</i>	=	<i>Commercial Crew Development Round 1</i>
<i>CCDev2</i>	=	<i>Commercial Crew Development Round 2</i>
<i>CCiCap</i>	=	<i>Commercial Crew Integrated Capability</i>
<i>CCP</i>	=	<i>Commercial Crew Program</i>
<i>CCtCap</i>	=	<i>Commercial Crew Transportation Capability</i>
<i>CCTS</i>	=	<i>Commercial Crew Transportation System</i>
<i>COTS</i>	=	<i>Commercial Orbital Transportation Services</i>
<i>CPC</i>	=	<i>Certification Products Contract</i>
<i>GMO</i>	=	<i>Ground and Mission Operations</i>
<i>IP</i>	=	<i>Integrated Performance</i>
<i>ISS</i>	=	<i>International Space Station</i>
<i>MMI</i>	=	<i>Mission Management and Integration</i>
<i>NASA</i>	=	<i>National Aeronautics and Space Administration</i>
<i>PC&I</i>	=	<i>Program Control and Integration</i>
<i>PCM</i>	=	<i>Post Certification Mission</i>
<i>SAA</i>	=	<i>Space Act Agreement</i>
<i>STRB</i>	=	<i>Safety Technical Review Board</i>
<i>SE&I</i>	=	<i>Systems Engineering and Integration</i>
<i>V&V</i>	=	<i>Verification and Validation</i>

I. Introduction

During a session back in 2009, the Shuttle Program passed before Congress where its retirement was to be announced. Two years later it took its final flight ultimately ending the program and America's capability to send its own astronauts to space. Since 2011 the U.S. has been dependent upon Russia to launch crews to the ISS and return them safely to Earth at the price of \$81 million a seat. Along with the budget cuts, NASA couldn't afford to return human-rated spaceflight back to the U.S. on its own, so the agency was forced to adapt. A new program, facilitated by NASA, would partner with domestic aerospace companies to develop and provide a cost-effective, safe, and reliable means to the International Space Station, and this adaptation would be called the Commercial Crew Program. Historically, the design and requirements of a commercial crew transportation system (CCTS) were contrived by NASA engineers then a contractor was selected to fabricate it. NASA would then oversee every step of fabrication, was thoroughly involved in testing, and owned whatever was being built i.e. a spacecraft, software,



ground facilities, etc. The Commercial Crew Program has drastically changed the agency's role in the development of America's next CCTS. Now, the companies have complete control of the design and ownership of the fabricated system; spacecraft, launch vehicle, and in some cases even the ground facilities. These companies then compete against each other to obtain a contract with NASA. By signing a contract the company, or commercial partner, agrees to adhere to a set of pre-determined safety requirements established by NASA for mission assurance, crew safety, and interfacing with the ISS.

II. Program Evolution

A. Commercial Crew Development Round 1 (CCDev1)

In 2010, CCP commenced with CCDev1 to begin partnering with domestic companies using Space Act Agreements (SAA). A SAA allows NASA to partner with various companies to advance program objectives. After retirement of Shuttle, the return of human spaceflight capability to America rested upon the shoulders of private industry. NASA devoted \$49.8 million worth of funds to stimulate private interest in developing America's new CCTS. CCDev1 consisted of 5 different aerospace companies, to which these funds were divided amongst, to start designing the subsystems for the CCTS; life support, guidance and navigation, spacecraft, launch vehicle, and many more.

B. Commercial Crew Development Round 2 (CCDev2)

In April of 2011, CCP entered into CCDev2 with 7 companies. Still using SAAs, \$315.5 million was split between 4 of the companies and the 3 additional companies signed unfunded agreements with NASA to further cultivate a network of collaboration. As the companies further developed their designs, "NASA reviewed and provided expert feedback on overall concepts and designs, systems requirements, launch vehicle compatibility, testing and integration plans, and operational and facilities plans" (Siceloff, 2016). This second round of development aimed to make actual systems out of the subsystems designed in the first round of development.

C. Commercial Crew Integrated Capability (CCiCap)

CCiCap began August 2012 as the last SAA funded stage of CCP. \$1.167 billion was awarded to 3 companies; Boeing, SpaceX, and Sierra Nevada Corporation. Here the companies were to integrate the systems they developed in round 2 and begin testing. The integrated designs were verified and validated for maturity.

D. Certification Products Contract (CPC)

December 2012 the program awarded its first contracts to 3 companies, permitting the certification of their CCTSs to fly NASA astronauts. CPC was the first phase of the 2 phase certification process. CCP worked very closely with the partners to coordinate their performance and safety requirements to NASA's human spaceflight requirements. These requirements are to ensure nominal performance of the mission, safety of the crew, and spacecraft interface with the ISS. In this phase, the program worked the companies' alternate standards, variances, hazard reports and certification and Verification & Validation (V&V) plans. The amount of \$29.582 million was apportioned between the companies.

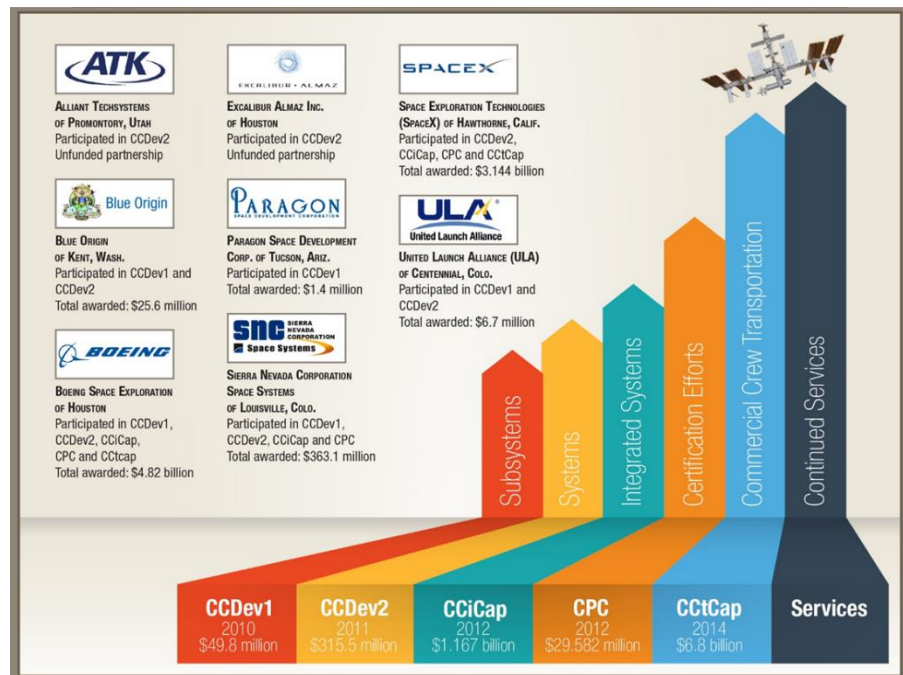


Figure 1. A Commercial Crew graphic summarizing all the companies involved and the evolution of the program.

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E. Commercial Crew Transportation Capability (CCtCap)

CCP is currently in this second phase of certification which began September 2014. After open competition down-selected the companies, fixed-price contracts were awarded to Boeing and SpaceX. A total of \$6.8 billion was awarded under CCtCap contracts. This phase is a continuation of NASA certification efforts to ensure that the partners' CCTSs are capable of safely transporting crews to the ISS. As part of this certification, they will have to perform one unmanned test flight and then a manned one. Once certified, each partner is then required to perform at least 2 and up to 6 Post Certification Missions (PCM).



Figure 2. Boeing conducts drop-test on their spacecraft, the CTS-100 Starliner.



Figure 3. SpaceX performs parachute drop test as part of CCtCap certification.

F. Services

After the PCMs NASA will then allow companies to compete for a continued ISS services contract.

III. Program Structure

A. Spacecraft and Launch Vehicle

Although two separate divisions, they perform the same duties only one is focused on the spacecraft and the other the launch vehicle. When a commercial partner signs a contract with NASA they agree to a set of pre-determined safety requirements listed in documents CCT-PLN-1120, CCT-REQ-1130, and SSP 50808. These documents provide safety, development, interface, and performance requirements between the ISS and Commercial Orbital Transportation Services (COTS) (see appendices for document summaries). The Spacecraft and Launch Vehicle offices are responsible for ensuring that the partner delivers on the requirements specified in the NASA documents for the associated element.

B. Integrated Performance (IP)

The IP office's job is much more technical compared to the other offices and heads the integrated performance of the CCTS. It assesses whether the commercial partner's CCTS is fulfilling integration performance requirements by renewing partner data and also conducting independent V&V through modeling. IP then is responsible for approving analogous verifications and requirements.

C. Ground and Mission Operations (GMO)

GMO manages pad operations, supports launches and mission activities, provides contingency management, and provides technical oversight. A couple parts of managing pad operations include, overseeing the fueling process and assisting in scrub turnaround (the actions that must be taken if the launch is canceled). It also monitors the partners' manufacturing process and schedule, and any transportation of the vehicle or its parts. The office will support the provider on launch days and is even involved in launch countdown. Mission planning and training of the crew is also GMO's responsibility. Additionally, it aids the partner if an off-nominal event, or contingency, occurs. These contingencies could take the form of an abort, emergency crew egress, landing error or emergency, and any other



rescue operation. Lastly, GMO is ensuring that the providers are adhering to the development and related operational requirements.

D. Program Control and Integration (PC&I)

The PC&I office consists of 3 teams that manage Program Planning and Control, Program Integration, and Program Communication and Engagement. Program Planning and Control deals with the program's budget and civil resource management. Program Integration provides overall program data access control, schedule development and integration, and supports boards and reviews. Lastly, Program Communication and Engagement manages the integration of technical communication and deliverables within CCP. This office is also the formal interface of communication between NASA centers, senatorial offices, and the public.

E. Systems Engineering and Integration (SE&I)

SE&I integrates across the entire program and is where the overall certification effort is accomplished. Mission and life critical hazards are identified and mitigated by the STRB. Partners' designs then pass through to the V&V panel to finalize their compliance with the NASA requirements. After this finalization of their CCTS the companies secure agency certification approval.

F. Mission Management and Integration (MMI)

MMI is concerned with the big-picture aspect of CCP's objective, flying a NASA crew to the ISS and back on a commercial provider's CCTS. This office is entirely mission specific and is currently focused on the unmanned and manned test flights and PCMs slated under CCtCap. MMI coordinates with the ISS, manages the cargo/payload, and is responsible for training the crew. All these tasks undergo a Certification of Flight Readiness for each individual flight.

G. Technical Authority and Program Management

At the highest level of CCP there's a team providing technical expertise and a team managing the entirety of the program. Technical expertise is provided by a matrix of support such as Safety & Mission Assurance, Human Health and Performance, and the Flight Operations Directorate to verify that the partners' designs are sound. Program Management oversees all the offices and ensures they are keeping schedule and integrating properly.

IV. Safety Technical Review Board

A. Description and Procedure

The STRB resides under the SE&I division and oversees both the spacecraft and launch vehicle. The STRB uses the documents listed above to ensure that the companies are adhering to NASA safety standards to mitigate improbable, but catastrophic hazards, hazards that could lead to a loss of mission or crew.

There are hundreds of these hazards and they are individually identified, managed, and tracked in reports. Every report has the same structure; causes, controls, and verifications. After the description of the main hazard, a list of causes comprise the rest of the report. Each cause has a list of mitigating controls, then each control is verified for legitimacy. Controls are often sensors/monitoring, meeting NASA documented safety requirements, failure tolerance components, procedures/sequences, inherent design, pre-implemented mitigations, etc. The verifications that validate these controls are generally inspection by a NASA engineer, analysis, qualification and acceptance testing, proving compliance with NASA requirements, etc. These reports then, individually, go to board where NASA determines if the partner has done all they can in mitigating that hazard, if so then it is approved. If NASA is dissatisfied with the partner's data or results the report will be deferred. The company then must rework the hazard mitigations and the report will return to board for review.

B. Contributions

My mentor is the STRB (Spacecraft) Chairman, so all the work I did with CCP was under the STRB. Mostly, I worked with the hazard reports and my first assignment was to create a metrics to log and track the reports through the approval and revision process. In the above paragraph I explained how the reports mitigate an improbable, but catastrophic cause by listing controls. In many cases, a hazard report will reference another report in the controls (also called a transfer) for information since some of them are very closely related. While that is permitted, a serious issue arises; the reports are constantly being revised if they are deferred after going to board. Any reports referencing that deferred report are in jeopardy of promising information that may have changed or has been entirely omitted. My metrics logged every transfer in every report and was constantly updated to accommodate the revisions. I actually



spoke a couple times during in a STRB if a transfer in a partner's report didn't deliver on the information it had promised.

Another task assigned to me was quite technical. I researched a certain failure mode that the STRB was concerned with and determined if it was insignificant or should be looked at more in depth. As part of my research I contacted and questioned a number of companies about their experience with a certain failure mode associated with the component. I then talked to the contractor actually fabricating the component, we discussed whether or not it was a

legacy product, its failure history, and their methods of testing. I presented my findings to CCP's Program Control Board chaired by the CCP Program Manager. I began with stating the information we had and what was lacking, how I gathered my data and what it was, and then gave my recommendation. After that assignment, I focused on a different failure of the component. My objective was to verify if a contractor's qualification and acceptance testing plan was sensitive enough to detect a leak rate to the precision NASA required. Using geometry provided in part drawings, I calculated what the contractor would have to detect in their testing. Then going back and analyzing their qualification and acceptance testing plan, I determined if they were capable of observing the precision that would be required of them.



Figure 4. Graphic showing specs of the commercial partners' spacecraft and launch

flight to become fully certified. The companies will provide a minimum of 2 and maximum of 6 NASA crew and/or cargo missions to and from the ISS to fulfill the CcTcap contract. NASA will then open competition to companies for a follow-on contract for ISS services.

V. Future Work

Since CCP is currently in CcTcap, the second phase of certification, it's working rigorously with the commercial partners to certify their vehicles for human-rated spaceflight. This includes certifying everything that makes up the vehicle; life support, environment control, abort system, software, avionics, propulsion, guidance and navigation, etc. This phase of the program is extremely intensive and the most time consuming. Afterwards, the partners must perform a successful unmanned and manned test

Appendix A

Crew Transportation Technical Management Processes (CCT-PLN-1120)

CCT-PLN-1120 provides NASA's expectations for the commercial partners' technical management processes. These expectations pertain to design and development, testing, evaluation, and certification processes.

Appendix B

ISS Crew Transportation and Services Requirements Document (CCT-REQ-1130)

CCT-REQ-1130 provides commercial partners with requirements for the development of their services to transport crew and cargo to and from the ISS. There are NASA requirements for every step of development from the design to testing and qualification and to actual operation.



Appendix C

ISS to COTS Interface Requirements Document (SSP 50808)

SSP 50808 provides the interface and performance requirements between the commercial partners' COTSs and the ISS. This NASA document ensures that the partners' vehicle can safely interface with the ISS. This document in conjunction with CCT-REQ-1130 list all the crucial ISS requirements for the companies' CCTS design.

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